

5. HIGHLIGHTS OF LABORATORY ACTIVITIES IN 2006

This section highlights the Laboratory's accomplishments for 2006. The summaries are written by the Branch Heads, and give examples of the research carried out by Branch scientists and engineers. Additional activities are described in Section 5.4, Laboratory Research Highlights. These highlights are supplemented by news items related to the Laboratory in Appendix 1, by a complete listing of refereed articles that appeared in print in 2006 in Appendix 2, and by the first page of highlighted journal articles in Appendix 3. For more details on Branch science activities, the Branch Web sites can be accessed from the Laboratory for Atmospheres home page at <http://atmospheres.gsfc.nasa.gov/>.

5.1 Mesoscale Atmospheric Processes Branch, Code 613.1

The Mesoscale Atmospheric Processes Branch (MAPB) seeks to understand the contributions of mesoscale atmospheric processes to the global climate system. Research is conducted on the physical and dynamical properties and on the structure and evolution of meteorological phenomena, ranging from synoptic scale down to micro-scales, with a strong focus on the initiation, development, and effects of cloud systems. A major emphasis is placed on understanding energy exchange and conversion mechanisms, especially cloud microphysical development and latent heat release associated with atmospheric motions. The research is inherently focused on defining the atmospheric component of the global hydrologic cycle, especially precipitation, and its interaction with other components of the Earth system. Branch members participate in satellite missions and develop advanced remote sensing technology with strengths in the active remote sensing of aerosols, water vapor, winds, and convective and cirrus clouds. There are also strong research activities in cloud system modeling, and in the analysis, application, and visualization of a variety of data.

The MAPB currently consists of 64 people. Demographically, there are 14 civil service scientists (11 with Ph.D.s) and one civil servant clerical. Three retired civil servants maintain Emeritus positions within the branch. Two more Project Scientists (Arthur Hou/GPM and Robert Adler/TRMM) are co-located in the Branch. The Branch maintains Cooperative Agreements with four institutions (UMBC/GEST, UMBC/JCET, GMU and UMCP/ESSIC), which collectively, comprise 28 scientists and programmers (21 Ph.D.'s). Since 1990, the Branch has had a contractual relationship with SSAI of Lanham, MD, for scientific, engineering, computer and administrative support. The level of support is currently 17 on-site and 3 off-site personnel. Four other support personnel are employed by ADNET, SGT, SAIC and Ecotronics.

The Branch maintains a Web site at <http://atmospheres.gsfc.nasa.gov/meso/>, where current information of projects, field campaigns, publications, and personnel listings can be found. An important Branch asset is the GOES Project Science Web site (<http://goes.gsfc.nasa.gov/>) which displays real-time GOES imagery, and provides free high-quality data to the scientific community. For example, in a non-hurricane month (May 2006), the site served 50 GBytes/day to 46 thousand distinct hosts at the average rate of 2 requests per second. During a hurricane, the Web server typically maxes-out at its limit of 10 requests per second to 150 simultaneous guests. The TRMM Web site (<http://trmm.gsfc.nasa.gov/>) provides near-real-time precipitation estimations every 3 hours (with daily and weekly accumulations) as well as flood potential maps http://trmm.gsfc.nasa.gov/publicatons_dir/potential_flood.html. A brief synopsis of virtually every major hurricane, typhoon, and flood event around the globe with attendant maps of accumulated precipitation can be found at http://trmm.gsfc.nasa.gov/publications_dir/multi_resource_tropical.html.

The Branch activities fall into three main subject areas, precipitation (and attendant climate-scale research), instrument development and data analysis (primarily lidars and radars), and numerical modeling. These are described in more detail below.

Precipitation

Branch scientists develop retrieval techniques to estimate precipitation using satellite observations from TRMM and other satellites, such as GOES and the AMSR-E sensor on EOS Aqua. The major accomplishments this year were

in the areas of TRMM algorithm improvement and achievement of continued operation of the TRMM satellite. In particular, there were significant publications on the TRMM Microwave Imager precipitation and latent heating profile products. The overall accuracy of the TRMM algorithms continues to improve. The TRMM Ground Validation team supports this achievement through processing and analysis of data from rain gauge networks and ground-based radars. This team provides reliable, instantaneous area- and time-averaged rainfall data from several representative tropical and subtropical sites worldwide for comparison with TRMM satellite measurements. Eight years of high quality data are now available through the Goddard DAAC. TRMM and other precipitation/latent heating data are used within the Branch for a wide spectrum of studies on precipitating cloud systems and the global water and energy cycles. Increasingly, these activities integrate global or regional data sets with modeling. Research is conducted on the assimilation of TRMM observations into models to explore the potential benefits to weather forecasting, such as for hurricanes, and to improve understanding of precipitating cloud systems, particularly the diurnal cycle. Branch scientists are also an integral part of the developing Global Precipitation Measurement (GPM) mission. Significant progress has been achieved in formulating this mission including incorporation of high-frequency channels for the GPM Microwave Imager to improve light rain and snowfall measurement capabilities. Various NASA and international workshops and meetings were held to advance the formulation of the mission and validation program. New approaches to validation, including physical validation of the precipitation parameterizations used in algorithms are being investigated. An experimental global monitoring system for rainfall-triggered floods and landslides using the 3-hour TRMM precipitation product is currently under development. See the Laboratory Research Highlights, Section 5.4.2, for more information on this important effort.

Instrument Development and Data Analysis

Development of lidar technology and application of lidar data for atmospheric measurements are also key areas of research. Systems have been developed to characterize the vertical profile structure of cloud systems (CPL), atmospheric aerosols (MPLNET), water vapor (SRL and RASL), and winds (GLOW) at fine temporal and/or spatial resolution from ground-based or airborne platforms. In addition, CPL and the Cloud Radar System (CRS), millimeter-wavelength radar for profiling cloud systems, have been integrated on NASA's high altitude WB-57F research aircraft for use in sensing the microphysical properties of cirrus and other cloud types. During July and August, 2006 the CPL and CRS were flown on the high-altitude ER-2 aircraft for the specific purpose of validating the newly launched CALIPSO and CloudSat satellites. The CPL and CRS are simulator and validation tools for CALIPSO and CloudSat, respectively (see Section 4.2.9), and their importance to the satellite validation activity underscores the role of suborbital instrumentation in the Branch.

Development of three instruments funded from the IIP continued. These were: TWiLiTE, an airborne direct detection Doppler lidar to measure wind profiles through the troposphere (0–17 km) using the laser signal backscattered from molecules; HIWRAP, a conical scanning Doppler radar to provide horizontal winds within precipitation and clouds, and ocean surface winds in addition to more traditional 3-D radar reflectivity and hydrometeor characteristics; and the Airborne Water, Aerosol, Cloud, and Carbon Dioxide Lidar - an Airborne Raman Lidar to simultaneously profile water vapor mixing ratio, aerosol backscattering, extinction and depolarization, and cirrus cloud properties, as well as cloud liquid water and carbon dioxide concentration. Development of these exciting new capabilities presents a major challenge.

GLAS (the Geoscience Laser Altimeter System) was successfully launched aboard the Ice, Cloud and Land Elevation Satellite (ICESat) in early 2003. GLAS is an important part of NASA's Earth Science Enterprise (ESE), which includes a series of satellites to measure Earth's atmosphere, oceans, land, ice, and biosphere for a period of 10 to 15 years. During 2006, GLAS data analysis contributed to five submitted journal publications. Among the topics covered by these papers were observations of tropopause level thin cirrus, the comparison of these observations with model-derived (MM5) clouds, and a comparison of cloud cover statistics between GLAS and HIRS. See the Laboratory Research Highlights, Section 5.4.3, for more information.

The Micro-Pulse Lidar Network (MPLNET – see Section 4.3.5) is a federated network of lidars co-located with sun photometers in the Aerosol Robotic Network (AERONET). MPLNET provides continuous profiles of aerosol and cloud distribution at a number of sites worldwide for various science applications and CALIPSO validation. Layer height and extinction products are also provided; all data and network information are available on our Web site: (<http://mplnet.gsfc.nasa.gov/>). There are currently 10 active sites in the network: 3 in the U.S., 3 in Asia, 2 in Antarctica, 1 in the Arctic, and 1 off the west coast of Africa. Data from several of the sites are publicly available on our Web site, and the remaining sites will soon be public after calibrations are completed. Older data sets from an additional 14 field campaigns are also available. Planning is underway for future sites in 2007-2010, including additional sites in the U.S., Asia, and the west coast of Africa, and new sites in the Caribbean, South America, and the Middle East. MPLNET results were compared against competing techniques and were found to have one of the lowest bias errors of all the methods available. Profiles of aerosol extinction are a primary MPLNET data product and an important data product to validate CALIPSO. The paucity of aerosol profile data is a major source of uncertainty in assessing global and regional climate models.

The Raman lidar group is engaged in a broad range of research involving development and use of technologies for studying atmospheric quantities and processes. The major activities of the group concern 1) Aqua and Aura satellite measurement validation; 2) development of an airborne Raman lidar with the ability to profile water vapor, aerosols, clouds and other quantities during both day and night; and 3) development of the capability to remotely quantify aerosol physical properties using multi-wavelength Raman lidar. Two University of Maryland Baltimore County (UMBC) Ph.D. graduate students and one Ph.D. graduate student from the University of Maryland College Park (UMCP) are supported and a total of three visiting scientists have worked with the group during this past year: one each from Russia, Bolivia and Brazil.

There is also a substantial effort and collaboration with Howard University (HU) graduate students and faculty at the HU Beltsville Research Campus. The Raman group designed and taught a lidar techniques and analysis course offered as a special topics course within the Physics Department, an Introduction to Meteorological Instruments (PHYS 590) as well as Aerosol and Cloud Physics (PHYS 525) at HU. The WAVES-2006, (see Sections 4.2.10 and 6.2) campaign was held at the HU Beltsville Research Campus, not far from GSFC. The goals of WAVES-2006 were to bring a diverse instrumentation set to one place for validation of satellite water vapor, ozone and clouds. Validation activities that address AIRS and CALIPSO instruments are also in progress using the data. About twenty undergraduate and graduate students and many scientists from Howard University, GSFC, Penn State, Univ. of Virginia, Univ. of Colorado, NCAR, Maryland Department of Environment, USDA, NWS and scientists from Italy, Bolivia, and Brazil participated in WAVES-2006. Details of WAVES-2006, including links to activities, goals, pictures and more can be found at <http://ecotronics.com/lidar-misc/WAVES.htm>.

The lidar group also participated in the Measurements of Humidity in the Atmosphere: Validation Experiments (MOHAVE, see Section 4.2.11) experiment at JPL's Table Mountain Facility near Pasadena, CA. The MOHAVE deployment was to support the validation of satellite measurements under the framework of the Network for the Detection of Atmospheric Composition Change (NDACC), formerly known as the Network for the Detection of Stratospheric Change (NDSC). Scientists and students from Howard University and JPL joined the Raman lidar team at MOHAVE. MOHAVE involved several remote sensing and *in situ* techniques and was very successful with more than 40 balloon launches and over 240 hours of lidar measurements.

Numerical Modeling

The branch is active in the development, improvement and application of atmospheric modeling systems. Three major development efforts were achieved in the past year. The finite volume General Circulation Model (fvGCM, see also Section 5.4.4) and Goddard Cumulus Ensemble (GCE) model, a cloud-resolving model, were coupled in a multi-scale modeling approach. The use of the fvGCM allows global coverage, and the GCE model provides explicit simulation of cloud processes and their interactions with radiation and surface processes, in contrast with conventional

parametric approaches. This modeling system has been applied and tested for two different climate regimes, El Niño (1998) and La Niña (1999). The new, coupled modeling system produced more realistic propagation and intensity of tropical rainfall systems, diurnal variation of rainfall over land and ocean and intra-seasonal oscillations, which are very difficult to forecast using conventional GCMs. A second major effort involved coupling various NASA Goddard physical packages (microphysics, radiation, and land surface models) into a next generation weather forecast model (known as the Weather Research and Forecast model or WRF). The new, coupled modeling system allows better forecasting (or simulation) of convective systems and tropical cyclones. Lastly, an improved GCE modeling system has been developed at Goddard over the last two decades. The GCE model has been recently improved to simulate the impact of atmospheric aerosol concentration on precipitation processes and the impact of land and ocean surface processes on convective systems in different geographic locations. The improved GCE model has also been coupled with the NASA TRMM microwave radiative transfer model and the precipitation radar model to simulate the satellite observed brightness temperature at various frequencies. This new, coupled model system allows us to investigate tropical cloud processes and improves the precipitation data retrieved from NASA satellites.

The same microphysical, long- and shortwave radiative transfer, explicit cloud-radiation, and cloud-surface interactive processes are applied in all three modeling systems. The results from these modeling systems were compared to NASA high-resolution satellite data (i.e., TRMM, CloudSat) in terms of surface rainfall and vertical cloud and precipitation structures. The model results were also compared to NASA and non-NASA field campaigns. The scientific output from the modeling activities was again exceptional in 2006 with 11 new papers published, in press, or accepted.

Branch scientists conducted research in the areas of hurricane formation, structure, and precipitation processes with an emphasis on storms that occurred during special NASA field programs such as CAMEX-4 and the TCSP experiment. Numerical forecast models, such as Mesoscale Model 5 (MM5) and WRF, were applied to simulate observed storms at very high grid resolution. The results were compared to field program and satellite (e.g., TRMM) measurements. Analysis of results for Hurricane Erin (CAMEX-4, 2001) led to improved understanding of precipitation organization, storm structure, and their relationship to intensity change and environmental influences. A study of the formation of Tropical Storm Gert (TCSP, 2005) is leading to improved knowledge of the processes that contribute to storm formation. Numerical models and TRMM satellite data are also used to study the organization of precipitation in winter storms, the mechanisms responsible for that organization, as well as climatological aspects of winter precipitation at lower mid-latitudes (approximately 24–35°N).

Retrieved temperature and humidity profiles from the AIRS instrument suite on the NASA Aqua satellite were used to simulate the Saharan Air Layer (SAL) and its influence on the formation of Hurricane Isabel (2003) with the MM5 model. By incorporating the AIRS data, MM5 better simulates the large-scale flow patterns and the activity of Hurricane Isabel in terms of the timing and location of formation and the subsequent track. It was demonstrated that the SAL suppresses Atlantic tropical cyclone activity by increasing the vertical wind shear, reducing the mean relative humidity, and stabilizing the environment at lower levels.

5.2 Climate and Radiation Branch, Code 613.2

One of the most pressing issues we face is to understand the Earth's climate system and how it is affected by human activities now and in the future. This has been the driving force behind many of the activities in the Climate and Radiation Branch. We have made major scientific contributions in five key areas: hydrologic processes and climate, aerosol–climate interaction, clouds and radiation, model physics improvement, and technology development. Examples of these contributions may be found in the list of refereed articles in Appendix 2 and in the material on the Code 613.2 Branch Web site, <http://climate.gsfc.nasa.gov>.

Key satellite observational efforts from the branch include MODIS algorithm development and data analysis. The new MODIS “collection 5” processing stream began in April 2006, starting with Aqua MODIS data. This processing stream includes substantial enhancements and updates to the operational cloud and aerosol products developed in the

branch (see Sections 4.3.4 and 5.4.1). The availability of MODIS cloud and aerosol products is opening new pathways of research in climate modeling and data assimilation in the Laboratory. MODIS data analysis efforts included the role of 3D radiative effects on aerosol retrievals and a number of studies of 3D and non-plane parallel effects on cloud retrievals.

The MODIS-derived global annual direct aerosol radiative forcing over clear sky oceans was estimated to be $-5.3 \pm 0.6 \text{ Wm}^{-2}$. Attempts to quantify aerosol indirect effects on clouds included combining in-situ cloud microphysics in California marine stratocumulus with TOA broadband CERES observations. An approach to quantifying the indirect effect on precipitation involved continuing analysis of six years of TRMM data which shows the existence of a weekly cycle. Over the continental U.S. in summer, rain intensity and area increase midweek when pollution is at its maximum while the opposite behavior occurs over nearby waters. This finding provides new insight into the influence of human activities on rainfall. The effect of aerosol loading on cloud cover using AERONET ground-based observations showed a positive correlation, in agreement with previous satellite studies.

Efforts to include explicit aerosol nucleation processes in climate models continued. Yogesh Sud led the McRAS (Microphysics of Clouds with Relaxed Arakawa-Schubert Scheme) effort. The new McRAS modules provide an end-to-end aerosol-cloud-radiation and precipitation scheme that explicitly handles CCN/IN activation and cloud formation, wet deposition, and cloud particle size distribution in fractional clouds for radiative calculations. The goal is to develop an aerosol- cloud-radiation interaction scheme that can credibly simulate direct and indirect aerosol effects.

In the applications area, high-resolution MODIS Aerosol Optical Depth (AOD) products (1, 2, and 5 km) are currently under evaluation as part of an on-going 3-dimensional air quality monitoring system project over the U.S. This 3-year effort (2006-2008) is funded by the NASA Application Program (Code YO), with a strong partnership with EPA (data system) and NOAA (air quality forecast). In addition, a 3-year Advanced Monitoring Initiative project (2006-2008) led at Goddard by Allen Chu (GEST/613.2), in support of GEOSS and funded by the EPA Pilot Program using high-resolution MODIS AOD products, is in full swing to study the air quality in the San Joaquin Valley, California. Both projects will incorporate CALIPSO, airborne, and ground-based lidar measurements to study the vertical distribution of aerosol. These two projects will provide insights into the relationship of satellite-derived AOD and *in situ* PM_{2.5} mass concentration (for particles sizes less than 2.5 μm).

Branch members continued participation in NASA sponsored field campaigns, including the deployments of the SMART-COMMIT ground-based platform in BASE-ASIA and NAMMA, and the MODIS Airborne Simulator on the ER-2 in the summer 2006 CALIPSO-CloudSat validation experiment (see Section 4.2.9). Branch members are expected to participate in NASA's Tropical Composition, Cloud and Climate Coupling (TC4) campaign (summer 2007) and the DOE ARM Cloud and LAnd Surface Interaction Campaign (CLASIC - June 2007).

We continue to serve in key leadership positions on international programs, panels, and committees. Robert Cahalan chaired the Observations Working Group of the Climate Change Science Program (CCSP) Office, tasked to evaluate and coordinate multi-agency contributions to the U.S. Government climate observing system. In addition, he was on a full-time detail at CCSP from August to December 2006. Cahalan received the Outstanding Leadership and Service Award by the Climate Change Science Program in 2006. Cahalan also chairs the 3-Dimensional Radiative Transfer Working Group of the International Radiation Commission and directs the International Intercomparison of 3-Dimensional Radiation Codes. Warren Wiscombe began his tenure as the DOE Atmospheric Radiation Measurement (ARM) Chief Scientist in October 2005; this appointment includes his half-time residence at Brookhaven National Laboratory. Wiscombe is also the American Geophysical Union (AGU) Atmospheric Sciences Section president.

Branch personnel continue to serve in key project positions. Robert Cahalan serves as project scientist of SOLar Radiation and Climate Experiment (SORCE) launched on January 25, 2003. SORCE is measuring both Total Solar Irradiance (TSI) and Spectral Solar Irradiance (SSI) with unprecedented accuracy and spectral coverage during a 5-year nominal mission lifetime. Deputy project scientists include Si-Chee Tsay (Terra), Steven Platnick (Aqua), and

Christina Hsu (NPOESS Preparatory Project, starting in November 2006). Associate branch member Michael D. King is the EOS Senior project scientist.

We continue to make strides in many areas of science leadership, education, and outreach. Thanks to the organizational efforts of the late Yoram Kaufman and the involvement of Lorraine Remer, Charles Ichoku (ESSIC/613.2) and other branch members, the popular AeroCenter seminar series has continued into a sixth year. The biweekly seminars attract outside aerosol researchers from NOAA and the University of Maryland on a regular basis. The AeroCenter visitor program continues to reap benefits including joint paper submissions.

The Goddard Sun-Climate Center, like AeroCenter, is a cross-cutting activity within Goddard's Sciences and Exploration Directorate, and is co-hosted by the Climate and Radiation Branch and the Goddard Solar Physics Laboratory. The Center sponsors research on solar system climate, and investigates new opportunities for advancing the understanding of the Sun's forcing of Earth's climate. Visiting scientists from Germany and Japan have joined this effort, and the Center receives advice from an international panel of experts. The Center sponsored a seminar series this past year, and will encourage new collaborations between scientists studying Earth, the Sun, and Earth's moon. See <http://sunclimate.gsfc.nasa.gov>.

The branch benefits from our close association with the GSFC Earth Sciences Education and Outreach Program, most of whose members (including program manager David Herring, Code 610.3) reside in branch space and utilize branch resources. This group produces the Earth Observatory Web site that continues to provide the science community with direct communication gateways to the latest breaking news on NASA Earth Sciences, as well as the more recent NASA Earth Observations (NEO) data set visualization tool.

Finally, we continue with timely updates (often daily) to the Climate and Radiation Branch Web site (<http://climate.gsfc.nasa.gov>). Its "Image of the Week" and "Latest News" items highlight research by Branch members. A search page provides easy access to archived news, images, publications, and other climate information and data. The site supports calendar subscriptions and also has an extensive glossary of Earth science acronyms and a list of links to related sites.

5.3 Atmospheric Chemistry and Dynamics Branch, Code 613.3

The Atmospheric Chemistry and Dynamics Branch develops computer models and remote sensing instruments and techniques as aids in studies of aerosol and ozone and other trace gases that affect chemistry, climate, and air quality on Earth. Using satellite, aircraft, balloon, and ground-based measurements, coupled with data analysis and modeling, Branch scientists have played a key role in improving our understanding of how human-made chemicals affect the stratospheric ozone layer.

Branch scientists have been active participants in satellite research projects. In the late 1960s, our scientists pioneered development of the Backscattered Ultraviolet (BUV) satellite remote sensing technique. Applying this technique to data taken from NASA and NOAA satellites, Branch scientists have produced a unique long-term record of the Earth's ozone shield. The data record now spans more than three decades, and provides scientists worldwide with valuable information about the complex influences of Sun, climate, and weather on ozone and ultraviolet radiation reaching the ground. Branch scientists expect to maintain this venerable record using data from a series of BUV-like instruments that are planned for use on U.S. and international satellites in the next two decades. Branch scientists were also instrumental in developing the UARS project which generates data used by researchers to produce a highly detailed view of the chemistry and dynamics of the stratosphere. Currently, Branch scientists are providing scientific leadership for the EOS Aura satellite, which was launched on July 15, 2004. Aura contains four advanced instruments to study the stratospheric ozone layer, chemistry and climate interactions, and global air quality. Branch scientists are also involved in the design of instruments, algorithms, and data systems for the new generation of ozone sensors on the operational weather satellites (NPP and NPOESS) and are developing state-of-the-art instruments to monitor air

quality and tropospheric chemical species from spacecraft located at high vantage points (at distances ranging from 20,000–1,500,000 km from Earth). In addition, they operate a suite of advanced active and passive remote sensing instruments to study the chemical composition of the Earth's atmosphere from ground and aircraft. The Branch has recently developed an advanced instrument and algorithm capability for ground-based validation of OMI satellite aerosol, NO₂, SO₂, and O₃ data.

The measurement activities of the Branch are highly coupled with modeling and data analysis activities. The Branch maintains state-of-the-art 2-D and 3-D chemistry models that use meteorological data, produced by the GMAO and other research centers, to interpret global satellite and aircraft measurements of trace gases. Results of these studies are used to produce congressionally-mandated periodic international assessments of the state of the ozone layer, as well as to provide a strategic plan for guidance in developing the next generation of satellite and aircraft missions. A major new thrust of the Branch is to apply the unique synergy between Branch modeling and measurement groups, which proved very successful for the study of stratospheric chemistry, to study chemically and radiatively active tropospheric species, including aerosol, CO₂, O₃, CO, NO_x, and SO₂, which affect climate, air quality, and human health. The Branch's expertise in modeling atmospheric composition, including aerosols, has generated a new initiative to develop a coupled chemistry-climate model, using the GMAO Global Circulation Model.

The following provides more detailed descriptions of some of the current Branch activities:

3-D Stratospheric Chemistry Model Studies

Branch scientists are analyzing a series of chemical transport model simulations of stratospheric ozone chemistry. These results are being compared with long-term data records from satellites and ground-based instruments. The goal is to use the model results to draw inferences about long-term ozone trends due to decrease in stratospheric chlorine and anticipated changes in the global climate.

The Branch is working collaboratively with the GMAO to couple chemistry to the dynamics in their general circulation models for chemistry–climate studies. The stratospheric chemistry used in the chemistry-transport studies has been coupled to the GEOS-4 GCM. The resulting chemistry-climate model has been integrated for 150 years simulating the period from 1950 through 2100. Additional simulations have been carried out for 1950 through 2050. Time-slice simulations with repeating conditions for 1980, 2000, and 2020 have been run for 25 years each. These simulations are directed at understanding the role of ozone in climate change over the coming decades and the role of climate change in modifying the response of ozone to CFCs. A feedback was found that causes ozone to increase in the middle stratosphere during the summer following the depletion during the Antarctic ozone hole. This result was verified using data from the SBUV series of satellites. Work is now underway to couple the chemistry to the GEOS-5 version of the GCM.

Global Modeling Initiative (GMI)

The goal of GMI is to develop and maintain a state-of-the-art modular 3-D CTM that can be used for assessing the impact of various natural and anthropogenic perturbations on atmospheric composition and chemistry, including the effects of aircraft. The GMI model also serves as a testbed for model improvements.

The GMI CTM has options for several chemical mechanisms for studying different problems. Recently, we have added a combined tropospheric-stratospheric mechanism for investigations of the climatically sensitive upper troposphere/lower stratosphere, and a microphysical aerosol mechanism for the study of aerosol size distributions and their role as cloud condensation nuclei. The chemical mechanisms have been recoded for compliance with the Earth Science Modeling Framework. The GMI model is being evaluated through comparison to satellite, aircraft, and ground-based measurements. The combined stratospheric-tropospheric model (COMBO), has been very successful in simulating the temporal and spatial distribution of ozone measured by Aura instruments, both in the stratosphere and upper troposphere. A “tape recorder” effect in CO measurements from MLS is reproduced by the model. This “tape recorder”

is driven by the seasonality of biomass burning. The model has also compared well with tropospheric ozone columns derived from OMI and MLS measurements, and with CO from the AIRS instrument. Work is in progress to extend the model validation to other constituents.

OMI Data Analysis

The OMI, built by Dutch/Finnish collaboration, was launched on NASA's EOS Aura satellite in July 2005. The primary objective of OMI is to continue the long-term record, created by Branch scientists, of total ozone, tropospheric ozone, UVB, aerosols (primarily smoke and desert dust), and volcanic SO₂ using data from NASA's TOMS instrument series. OMI is also designed to measure several other trace gases important for air quality studies, including NO₂, anthropogenic SO₂, HCHO, and BrO, with improved spatial and temporal resolution compared to data from previous instruments, the Global Ozone Monitoring Experiment (GOME) and the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY), on European satellites. Several Branch scientists are members of a NASA-funded U.S. science team, which is led by Pawan K. Bhartia. In 2005, Branch scientists developed and released several TOMS-like data products from OMI. Preliminary analysis shows that these data are of better quality and have significantly greater accuracy and precision than that from TOMS, particularly for SO₂. Several new products, not previously available from TOMS, have also been produced and are currently being validated. These include cloud parameters such as cloud pressure that are appropriate for use within the OMI trace-gas algorithms. Several scientific papers describing this work have appeared in journals in 2006 and more are expected in 2007.

Global Aerosol Studies

Aerosols affect climate by scattering and absorbing solar radiation and by altering cloud properties and lifetimes. They also exert large influences on weather, air quality, atmospheric chemistry, hydrological cycles, and ecosystems. To understand the roles that aerosols play in the Earth system and to determine the processes that control the aerosol distributions, Branch scientists have developed the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model which simulates major types of atmospheric aerosols and relevant trace gases originating from both anthropogenic and natural sources, such as fossil fuel combustion, biomass burning, desert, ocean, vegetation, and volcanoes. In addition to the original off-line version of the model which is driven by the GEOS-DAS assimilated meteorological fields from the Goddard Modeling and Assimilation Office (GMAO), the GOCART modules have been implemented into the on-line GEOS-GCM model as well as the Global Modeling Initiative (GMI) modeling framework in the past year by the Branch scientists to further enhance the modeling capability.

The modeling activities have been strongly connected to observations. For example, the model has been continuously used to analyze and interpret aerosol observations from satellite instruments of MODIS and MISR and from ground-based sun photometers in the AERONET network; the model output has been integrated into satellite observations to provide the best description of global aerosol distributions; the model vertical profiles of SO₂ and absorbing aerosols are being tested to help OMI retrievals; and the on-line model has been generating aerosol and CO forecasts to support field experiments such as the Aura Validation Experiments (AVE) and the NASA African Monsoon Multidisciplinary Analysis (NAMMA). The model has been a part of the international project AEROCOM (AEROSol Comparisons between Observations and Models) and will participate in the new international activities of Hemispheric Transport of Atmospheric Pollutants and the Atmospheric Chemistry and Climate initiatives.

Measurement and Modeling of Atmospheric Carbon Dioxide

Recent Laboratory progress in carbon cycle science has come in the areas of atmospheric transport modeling and instrument construction and testing. The atmospheric chemistry and transport model, used for calculating global CO₂ transport, has incorporated a land biosphere emissions model and satellite data-constrained biomass burning emissions to produce CO₂ fields that are closely tied to actual meteorology and emission events. The modeling group is actively participating in an international model intercomparison exercise, TransComC, which is aimed at improving

models' ability to utilize upcoming space-based CO₂ observations, such as the Orbiting Carbon Observatory. We are also collaborating with the GMAO in a new effort to develop a carbon cycle data assimilation system. We are in a collaborative effort with the Solar System Exploration Division to develop an airborne CO₂ laser sounder under the IIP. The modeling effort will help to optimize the sounder measurement characteristics through observing system simulation experiments. A partner instrument, the ground-based laser CO₂ profiler, is also being developed in the Laboratory for Atmospheres. The laser profiler has recently achieved CO₂ detection in reflection from clouds and has made range-resolved measurements of aerosols at both the online and offline wavelengths. This is the final step in making range-resolved measurements of CO₂ within the planetary boundary layer. The real-time CO₂ observations will be compared with modeled distributions to improve our knowledge of the coupling between carbon cycle processes and climate change.

Sun–Earth Connections

Two new instruments are nearing completion under the IIP, the Solar Viewing Interferometer Prototype (SVIP) and the GeoSpec (Geostationary Spectrograph). The SVIP is a 1.3 m prototype of an 8 m instrument that will make measurements between 1–4 μ to determine the amounts of CO₂, H₂O, O₃, N₂O, and CH₄ in the Earth's atmosphere from a position at L2. The SVIP is designed for testing in the laboratory, outside at Goddard, and on a mountaintop. The GeoSpec is a dual spectrograph operating in the UV/VIS and VIS/Near-Infrared (NIR) wavelength regions to measure trace gas concentrations of O₃, NO₂, and SO₂, coastal and ocean pollution events, tidal effects, and aerosol plumes. GeoSpec is intended to support future missions in the combined fields of atmospheres, oceans, and land. GeoSpec is a collaboration of our Laboratory, Pennsylvania State University, Washington State University, and Research Support Instruments. GeoSpec activities during the current year included final assembly of the breadboard model, radiometric testing, and validation work. A final report to ESTO was delivered in December 2006.

A commercial Brewer double-grating spectrometer has been modified for nearly continuous measurement of column aerosols, NO₂, and SO₂, by the direct-Sun technique. This instrument has traditionally been used for measurements of total ozone and UV irradiance. Polarization and multi-angle measurement capabilities have been added to test the possibility of deriving ozone profiles, as well as particle size and refractive indices of aerosols in the UV. The technology is being transferred to other Brewers around the world to form a network for satellite data validation.

An imaging polarimeter-spectrometer instrument is being developed using internal research and development funds to measure aerosol plume height from space using a passive remote sensing technique developed by Branch scientists.

A new aircraft-based measurement program was started in 2005. ACAM was test flown onboard the NASA WB-57F during the AVE in June 2005 flying out of Houston, Texas. This system combines high resolution photographic imagery of both nadir and forward-looking cloud conditions with nadir UV and VIS spectrographic measurements in order to map trace gas concentrations of NO₂, O₃, and aerosols. These measurements will be used to validate similar measurements from the OMI onboard Aura. The improved ACAM was flown in the CR-AVE mission during January and February 2006. A second version of ACAM is now being developed for deployment on a NASA UAV.

5.4 Laboratory Research Highlights

5.4.1 MODIS Data Processing

The MODIS Atmosphere Team is responsible for generating cloud, aerosol, and clear sky Level-2 (pixel-level) and Level-3 (gridded) products from the MODIS Terra and Aqua instruments. As a part of the latest MODIS Atmosphere Team reprocessing effort (referred to as "Collection 5"), the GSFC Level-2 cloud optical and microphysical properties algorithm (thermodynamic phase, optical thickness, effective size, water path) has been largely rewritten. In addition to a number of improvements, the updated algorithm includes new components that have never been incorporated into operational retrievals of this type, including: (1) pixel-level uncertainties for optical thickness, effective particle

size, and water path retrievals, along with estimates of the uncertainty in Level-3 gridded means; (2) development of a set of spatially-complete surface spectral albedo maps derived from the MODIS land albedo product and used in modeling above-cloud spectral reflectance; (3) retrievals derived from novel spectral band combinations; and (4) a research-level multilayer cloud detection product. All Level-2 retrievals from this algorithm are contained in the MOD06 and MYD06 product files (for MODIS Terra and Aqua, respectively). The algorithm is the responsibility of Michael. D. King (Code 610) and Steven Platnick (Code 613.2), as are the entire set of MODIS Atmosphere Team Level-3 (daily, eight-day, and monthly) algorithms.

The Aerosol Level-2 product (Lorraine. Remer, P.I., Code 613.2) includes a number of Collection 5 improvements, including new aerosol models and a new land algorithm. A new “Deep Blue” aerosol land algorithm, that includes use of the 412 nm MODIS band, will be implemented in Aqua MODIS Collection 5 processing (led by Christina Hsu, Code 613.2). Documents detailing individual Atmosphere Team algorithm modifications, improvements, and impacts are available at: http://modis-atmos.gsfc.nasa.gov/products_C005update.html.

The MODIS Atmosphere Team’s Aqua Collection 5 reprocessing effort began in April 2006 (along with Aqua forward processing) and was completed in June 2006. Aqua forward processing also began at the same time. Terra reprocessing began in July and was finished in December 2006. All MODIS Atmosphere Team Level-2 and Level-3 Collection 5 files, as well as Level-1B data, are now being distributed by the MODIS processing system (referred to as MODAPS) instead of the Goddard DAAC. All data are on disk and accessible via ftp. A host of other capabilities, including subsetting, subscription services, etc. are also available. The Web interface to this data distribution system is called LAADS (Level-1 and Atmosphere Archive and Distribution System). The Web interface can be found at: <http://ladsweb.nascom.nasa.gov/>.

For further information contact Steven Platnick (Steven.Platnick@nasa.gov).

5.4.2 Flood/Landslide Detection for Disaster Preparedness

Floods and associated landslides account for the largest number of natural disasters and affect more people than any other type of natural disaster. With the availability of satellite rainfall analyses at high-time resolution, it has become possible to assess such hazards on a near-global basis. A framework (Figure 5.1) to detect floods and landslides related to heavy rain events in near-real-time has been proposed. The acronyms in this figure that are not defined elsewhere are: SRTM; Shuttle Radar Topography Mapper, DEM; Digital Elevation Model, FD; Flow Direction, and FA; Flow Accumulation.

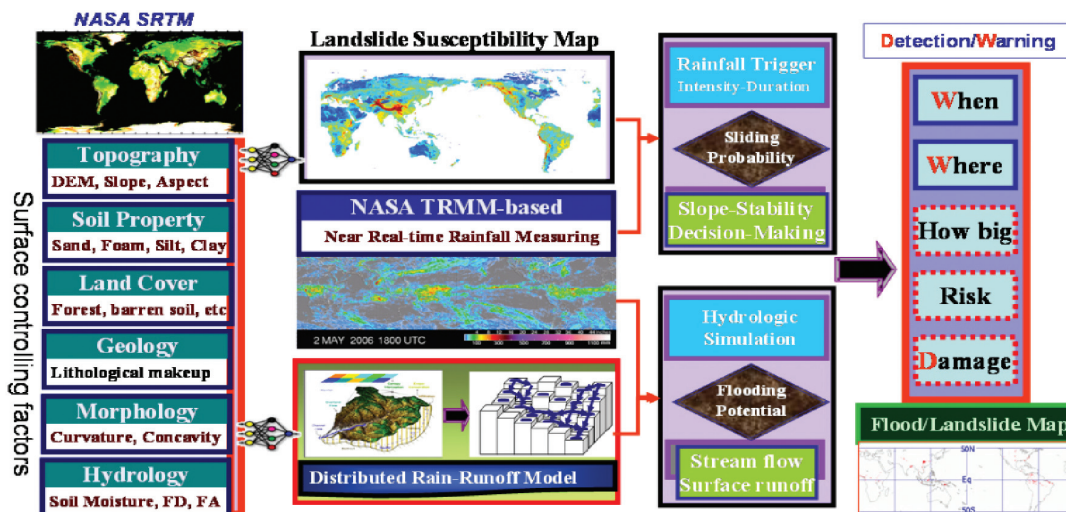


Figure 5.1. The conceptual framework for monitoring rainfall-triggered flood/landslides on a global scale.

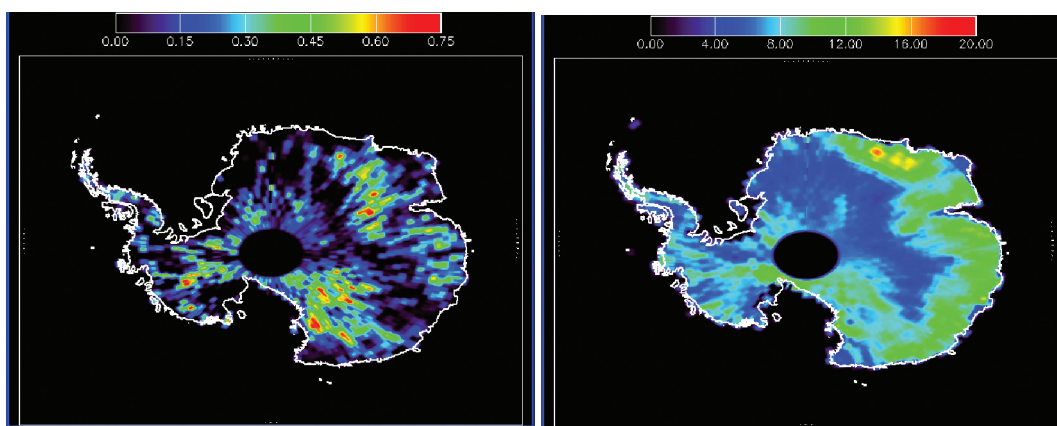
Key components of the framework are: a fine-resolution precipitation acquisition system; a comprehensive land surface database; a hydrological modeling component; and landslide and debris flow model components. A key data set for the integrated applications is the NASA TRMM Multi-satellite Precipitation Analysis. This data set provides near real-time precipitation at a temporal-spatial resolution of 3 hours and $0.25^\circ \times 0.25^\circ$. In combination with global land surface data sets it is now possible to expand regional hazard modeling components into a global identification/monitoring system for flood/landslide disaster preparedness and mitigation. For further information contact: Robert Adler (Code 613.1), Robert.F.Adler@nasa.gov.

5.4.3 The Geoscience Laser Altimeter System (GLAS)

GLAS was launched aboard the Ice, Cloud, and Land Elevation Satellite (ICESat) in early 2003. GLAS is an important part of NASA's Earth Science Enterprise (ESE) which includes a series of satellites to measure Earth's atmosphere, oceans, land, ice, and biosphere for a period of 10 to 15 years. During 2006, GLAS data analysis contributed to five submitted journal publications. Among the topics covered by these papers were observations of tropopause level thin cirrus, the comparison of these observations with model (MM5) derived clouds, and a comparison of cloud cover statistics between GLAS and HIRS.

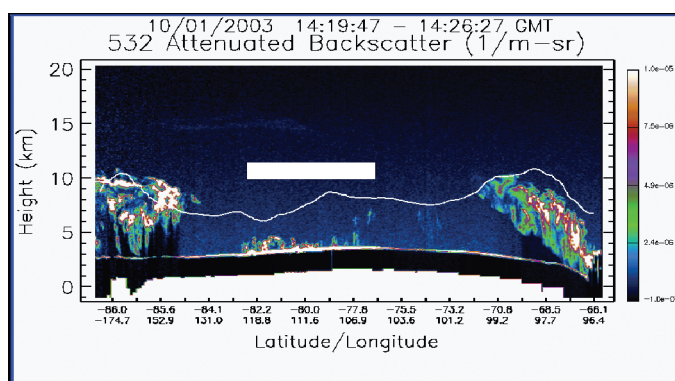
GLAS has provided the first global observations of the true height distribution of clouds and aerosols in the atmosphere. In addition to proposing and designing the atmospheric channels, data product algorithms have been developed that distinguish cloud and aerosol layers in the data and derive optical properties of layers. The GLAS data products have provided fundamentally new atmospheric science results. As the most accurate such measurement, GLAS shows the total global cloud cover is 76% and cloud overlap, defined as the detection of a second cloud layer before full optical attenuation, is found to be present in 40% of cloudy areas globally. From interpretation of the aerosol height distribution a unique global data product of planetary boundary layer (PBL) height has been produced. The PBL height data, and cloud distribution, have been applied to improve parameterization for the ECMWF and other global circulation models. In comparison to passive satellite retrievals, large improvements are provided in some crucial cloud and aerosol parameters. Major limitations in existing global cloud distribution climatology have been quantified, especially in polar regions. Many newly enabled studies in specialized areas are underway. A unique new result, highlighted below, is the detection of blowing snow across Antarctica, and its relation to winds.

The GLAS mission is the first of four spaceborne laser remote sensing experiments currently underway or in development by NASA and the European Space Agency.



Blowing snow frequency of occurrence for Oct. 2003 from GLAS data analysis.

Surface wind speed from NSIDC model for Oct. 2003.



GLAS data track across Antarctica. The heavy white line is where blowing snow at the surface is detected. The thin white line shows the relative wind speed.

Figure 5.2. Relationship of wind speed to blowing snow across Antarctica.

5.4.4 Hurricane Research

The hurricane research carried out by the Laboratory helps address the central question of NASA's mission in this area: How can weather/hurricane forecasts be improved and made more reliable over longer periods of time using computer modeling? To address this question we have used the computational power of the Columbia supercomputer at AMES research center running the finite-volume General Circulation model (fvGCM) to study, for example, five-day track predictions and the intensity evolution of Hurricane Katrina in August 2005. The term 'fvGCM' has been historically used to refer to the model developed over 10 years at the NASA Goddard Space Flight Center and previously referred to as the NASA fvGCM. In addition to the finite-volume core it now includes the NCAR Community Climate Model 3 (CCM3) physics and the NCAR Community Land Model (CLM)

As of July 2006, three articles highlighting computations completed on Columbia since it came on-line in summer 2004 have been published. Two of them have been selected as American Geophysical Union Journal Highlights, and one has been cited as pioneering work (by Professor Roger Pielke, Sr. of Colorado State University). Recently, an article for the high-resolution simulations of Hurricane Katrina (2005) has been highlighted in Science magazine.

The 2005 Atlantic hurricane season was the most active in recorded history. There were 28 tropical storms and 15 hurricanes, four of which were rated Category 5. Hurricane forecasts pose challenges for General Circulation Models

(GCMs), the most important being the horizontal grid spacing. It is well known that GCMs' insufficient resolutions undermine intensity predictions. Thanks to the considerable computing power of Columbia, this limitation can now be overcome. The main goal of this research, supported by NASA's Weather Data Analysis and Assimilation Program, Earth Sciences Division, is to study the impacts of increasing resolution on numerical weather/hurricane forecasts, aimed at improving forecast accuracy. With the unprecedented computing resources provided by Columbia, it was possible to increase the horizontal resolution of the fvGCM to 1/4 degree in early 2004 and 1/8 degree in early 2005. Improvement stemming from higher resolution was illustrated by calculation of the intensity evolution of hurricane Katrina in which six 5-day forecasts with the 1/8-degree fvGCM obtained promising forecasts with small errors in center pressure of only ± 12 hpa. It was also shown that the notable improvement in Katrina's intensity forecasts occurred when grid spacing decreased from 1/4 degree to 1/8 degree, which is sufficient to simulate the near-eye wind distribution and to resolve the radius of maximum winds. In addition to the computational issue, the validity of physics parameterizations poses a challenge to conducting ultra-high resolution simulations. Among these, convective parameterization (CP) is recognized as a crucial limiting factor affecting hurricane forecasts. The fvGCM was used with and without CP to simulate Katrina's track, intensity, and near-eye wind distribution.

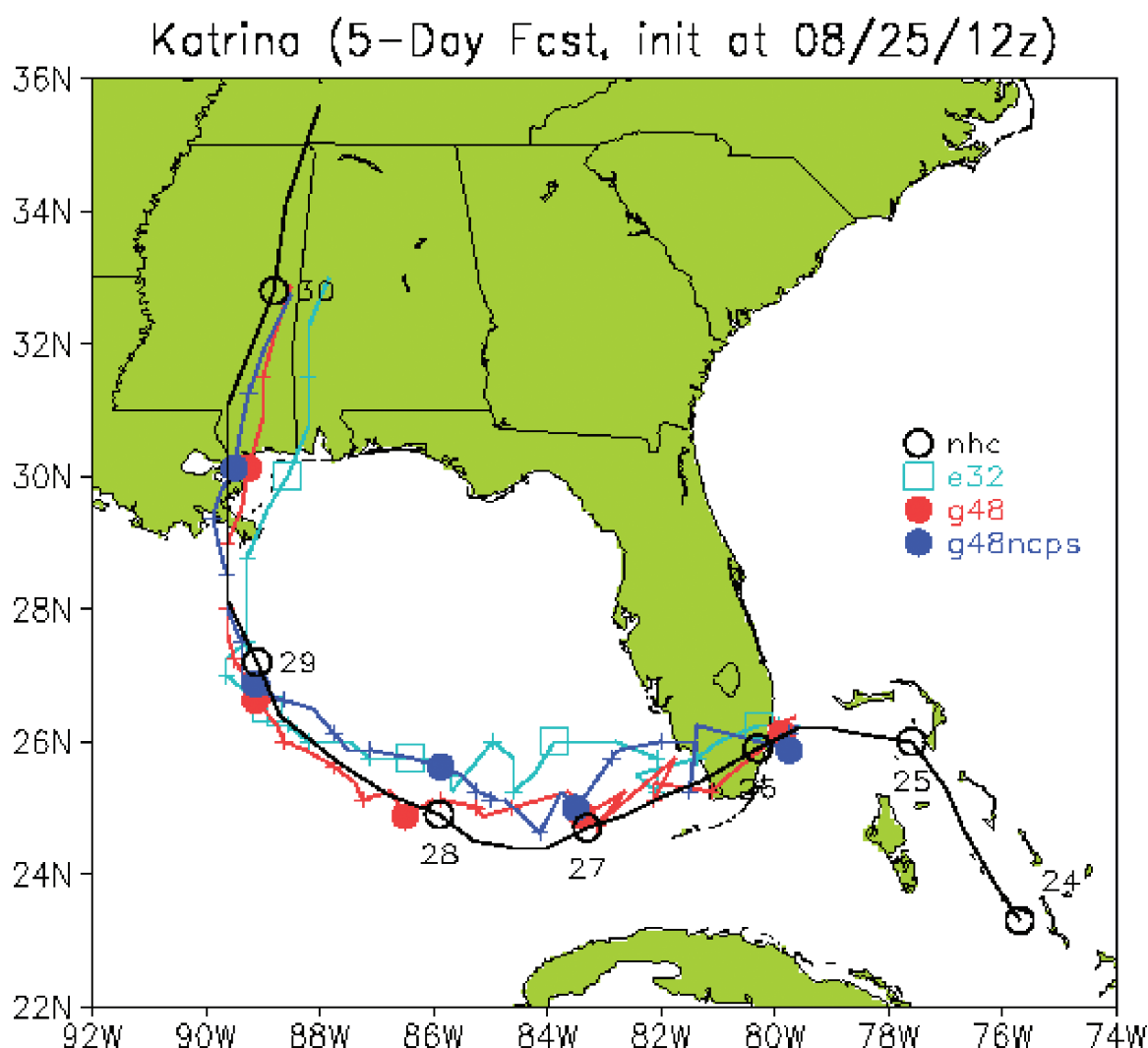


Figure 5.3. Five-day track predictions for hurricane Katrina initialized at 1200 UTC August 25, 2005. The light blue, red, and blue lines represent the tracks from 0.25°, 0.125° simulations, and 0.125° simulation with no CP. Each dot represents the center position at 3-hour time increments. The black line represents the advisory track with a 6-hour time increment from the National Hurricane Center.

Recently, the model's performance on intensity forecasts of major hurricanes was presented at the AGU 2006 Fall Meeting. In addition, the fvGCM at 1/12-degree resolution is being tested. The 1/12-degree fvGCM is the first global weather model with single digit resolution: 9 km at the equator and 6.5 km at mid-latitudes. For further information contact Bo-Wen Shen, Bo-Wen.Shen.1@gsfc.nasa.gov.

5.5 Instrument Development

The Instrument Systems Report, NASA/TP-2005-212783, described the status of instrument development in the Laboratory as of mid-2005. This section describes some of the developments since publication of that report.

5.5.1 High-Altitude Imaging Wind and Rain Airborne Profiler

A dual-wavelength (Ku and Ka band) High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) is under development for the NASA Instrument Incubator Program (IIP) for measuring tropospheric winds within precipitation regions and ocean surface winds in rain-free to light-rain regions. This instrument is being designed for operation on high-altitude manned aircraft and the Global Hawk UAV. Proposed lidar-based systems will provide measurements in cloud-free regions globally. Since many of the weather systems are in disturbed regions that contain precipitation and clouds, microwave-based techniques are more suitable in these regions. Airborne radars at NASA and elsewhere have shown the ability to measure winds in precipitation and clouds. These radars have not generally been suitable for deriving the full horizontal wind from above cloud systems (high-altitude or space) that would require conical scan. HIWRAP is a conical scan radar that uses new technologies that utilize solid state rather than tube-based transmitters. A prototype sensor will be completed and tested on the high-altitude WB-57F aircraft in late 2008 to demonstrate the system level performance of the instrument. For further information contact Gerry Heymsfield, Gerald.M.Heymsfield@nasa.gov.

5.5.2 Shared Aperture Diffractive Optical Element

ESTO funds the development of a Shared Aperture Diffractive Optical Element (ShADOE) telescope under their Advanced Component Technology program. The ShADOE telescope will eliminate most or all mechanical moving components by sequentially "addressing" several holograms multiplexed into a single optic in order to scan over the multiple fields of view. This last development should reduce the weight of large aperture scanning receivers by a factor of three. The objectives of the ShADOE project are as follows:

- Enable atmospheric Doppler (e.g. wind profiling) and surface-mapping lidar applications from space;
- Develop diffraction-limited holographic, or diffractive optical, elements for use with 2054 nm wavelength lasers and near-diffraction limited ShADOEs for use at 355 nm;
- Demonstrate an angle-multiplexed, multi-wavelength ShADOE telescope suitable for use with single and dual-wavelength lidars.

For more information on this technology, visit the Web site at <http://estips.gsfc.nasa.gov/qc/images/1158.jpg> or contact Bruce Gentry (Bruce.M.Gentry@nasa.gov).

5.5.3 Tropospheric Wind Lidar Technology Experiment

Global measurement of tropospheric winds is a key measurement for understanding atmospheric dynamics and improving numerical weather prediction. Global wind profiles remain a high priority for the operational weather community and also for a variety of research applications including studies of the global hydrologic cycle and transport studies of aerosols and trace species. In addition to space-based winds, a high-altitude airborne system flown on UAV or other advanced platforms would be of great interest for studying mesoscale dynamics and hurricanes. The TWiLiTE project is funded by ESTO as part of the IIP. TWiLiTE will leverage significant research and development investments in

key technologies made in the past several years. The primary focus will be on integrating these subsystems into a complete molecular direct detection Doppler wind lidar system designed for autonomous operation on a high-altitude aircraft, such as the NASA WB-57F, so that the nadir-viewing lidar will be able to profile winds through the full troposphere. TWiLiTE is a collaboration involving scientists and technologists from NASA Goddard, the NOAA Earth System Research Laboratory (ESRL), Utah State University Space Dynamics Lab, and industry partners Michigan Aerospace Corporation and Sigma Space Corporation. NASA Goddard and its partners have been at the forefront in the development of key lidar technologies (lasers, telescopes, scanning systems, detectors, and receivers) required to enable spaceborne global wind lidar measurement. The TWiLiTE integrated airborne Doppler lidar instrument will be the first demonstration of an airborne scanning direct detection Doppler lidar and will serve as a critical milestone on the path to a future spaceborne tropospheric wind system. For more information on this technology, visit the Web site at <http://estips.gsfc.nasa.gov/qc/images/1157.jpg> or contact Bruce Gentry (Bruce.M.Gentry@nasa.gov).

5.5.4 Airborne Water, Aerosol, Cloud, and Carbon Dioxide Lidar

The Airborne Water, Aerosol, Cloud, and Carbon Dioxide Lidar is being developed under the NASA IIP program's 2005 award. It is an outgrowth of the Raman Airborne Spectroscopic Lidar (RASL) developed under the first NASA IIP in 1998. The objectives of this program are:

Extend the development of RASL from a laboratory system to an automated, airborne Raman lidar system to conduct:

- (1) Day and night measurements of water vapor, aerosol backscatter, extinction, and depolarization.
- (2) Night measurements of cloud liquid water and carbon dioxide.

RASL is scheduled for test flights in June and July, 2007 aboard a Beechcraft King Air based at Bridgewater, VA. Upon successful testing, RASL will provide the first simultaneous airborne profile measurements of boundary layer aerosols and water vapor, permitting studies of hygroscopic aerosol growth. Coupled with the experimental measurements of cloud liquid water during the nighttime, aerosol indirect effect studies will be possible. Successful testing of RASL on a KingAir will also demonstrate the feasibility of adapting Raman Lidar to high altitude aircraft such as the Global Hawk and WB-57F. For further information see the following references:

1. Whiteman, D. N., G. Schwemmer, T. Berkoff, H. Plotkin, L. Ramos-Izquierdo, G. Pappalardo, Performance modeling of an airborne Raman water vapor lidar, *Appl Opt.*, 40, No. 3, 375–390. (2001).
2. Whiteman, D. N., S. H. Melfi, Cloud liquid water, mean droplet radius and number density measurements using a Raman lidar, *J. Geophys. Res.*, Vol 104 No. D24, 31,411–31,419 (1999).

or contact David Whiteman, David.N.Whiteman@nasa.gov.

5.6 Awards

5.6.1 Individual Awards

Thomas Bell (Code 613.2) received the Laboratory for Atmospheres Scientific Research Award “For outstanding scientific contributions towards understanding the Spatiotemporal Behavior of Rainfall inferred from Satellite and *in situ* Data.”

Scott Braun (Code 613.1) received a Goddard Honor Award for Earth Science Achievement “for significantly advancing the scientific understanding of tropical cyclones, especially the processes of hurricane intensification and genesis.”

Robert Cahalan (Code 613.2) received a NASA Exceptional Service Medal “For scientific leadership and service to NASA in representing NASA within the Climate Change Science Program, the Global Climate Observing System, and the Group on Earth Observations.”

Outstanding Leadership and Service Award, Climate Change Science Program

Belay B. Demoz (Code 613.1) was selected to receive the 2005 Editors’ Citation for Excellence in Refereeing for JGR-Atmospheres at the May 2006 AGU meeting in Baltimore.

Yoram Kaufman (Code 613.2) received the Verner E. Suomi Award given by the AMS.

Andrew Negri (Code 613.1); Richard Stewart (Code 613); on October 16 received an Acquisition Improvement Award for exemplary efforts on the Laboratory for Atmospheres and Scientific Technical Support Source Evaluation Board (SEB). The Acquisition Improvement Award is the highest Agency acquisition award, given only to individuals who provide a significant contribution in the procurement process.

Dr. W.-K. Tao (Code 613.1) was selected to receive the National Central University of Taiwan Excellent Alumni Award for 2006.

5.6.2 Group Achievement Awards

The TOMS Science and Data Processing Team

The 2006 Pecora Award was presented to Pawan Bhartia (Code 613) and the TOMS team on December 13 at the AGU meeting in San Francisco. The William T. Pecora Award is presented annually to individuals or groups that have made outstanding contributions toward understanding the Earth by means of remote sensing.

The UARS Team

The UARS Team was selected by the NASA Headquarters Incentive Awards Board to receive a Group Achievement Award at a ceremony and luncheon that was held on June 21, 2006 at Martin’s Crosswinds in Greenbelt, Maryland. UARS Project Scientist Charles Jackman (Code 613.3) accepted the award for the UARS team.

The TOMS Team

The TOMS team was awarded a Group Achievement Award at the same ceremony. EP-TOMS Principle Investigator Rich McPeters (Code 613.3) accepted the award for the TOMS team.

The Earth Observing System (EOS) Team

Bob Cahalan (Code 613.2) accepted the AIAA Space Systems Award on behalf of the Earth Observing System (EOS) Team.

NASA’s Ozone Watch Web Site

This Web site, at (<http://ozonewatch.gsfc.nasa.gov>), was chosen as a finalist in the Annual Webby Awards, as selected by the International Academy of the Digital Arts and Sciences for the “Science” category. The site was conceived and built under the direction of Paul Newman (Code 613.3), with contributions from the Aura and NASA Atmospheric Chemistry Science Community, GSFC Public Affairs, and design by Robert Simmon (Code 613.2, SSAI).